BEAM INSTRUMENTATION (WBS 1.8)

Operation of the collider and achievement of full design luminosity will require continuous monitoring of many beam characteristics. Initial instrumentation will include beam position monitors at each quadrupole and at additional locations in the insertions. In addition to the normal closed orbit measurements, commissioning and machine studies will require single-pass position and intensity monitoring of individual bunches. The DC beam current will be measured with a special transformer while the individual bunch shape will be monitored with a wideband wall current pickup. Feedback systems will be provided to suppress transverse instabilities and to correct for injection errors of individual bunches. Radiation monitors will be used in conjunction with the beam scraper system to identify and minimize beam losses. Luminosity monitors, required at each intersection region, will be part of the experimental equipment. A summary of beam instrumentation systems is shown in Table 8-1 and more detailed information on the most important items is given below.

i. Beam Position and Closed Orbit Measurement

The properties of the circulating beam will themselves be a very sensitive monitor of the performance of the superconducting magnets in each ring. It is planned to measure the position of the closed orbit, that is the center of the beam horizontally or vertically, at 246 locations in each ring, spaced at intervals of about one quarter betatron wavelength where vertical and horizontal β functions are maximum. This information can be exploited rapidly enough to be used in lattice control and feedback procedures in a real time sense without prolonging the expected acceleration time. In addition to measuring the closed orbit, which assumes no coherent transverse bunch motion, the electronics that processes the signals from the position monitors will also be capable of measuring the position of an individual bunch on a turn by turn basis. A bunch intensity measurement will also be provided.

The position monitors are itemized in Table 8-2. The beam position signals will be obtained with 50 Ω stripline pickups of approximately 20 cm length that sense both the electric and magnetic fields of the bunches. Most locations will contain striplines with one end connected to a 50 Ω coaxial cable that will transmit the signal to remotely located

Table 8-1. Beam Instrumentation

Instrument Total System	Basic Elements	Function	Number
· DC current transformer	Transformer/magnet modulator	Circulating beam intensity	2
· Luminosity monitor†	Scintillation counter telescopes/beam displacement coil	Measure beam collision rate	6
· Radiation loss monitor	Radiation detectors	Measure radiation loss background	382
· Position monitor	Stripline electrodes	Equilibrium orbit bunch position	480
· Wide band wall current monitor		Beam structure	2
· Tune Measurement & Transverse Damper	Stripline Kickers	Control of coherent motion	4
· Beam profile	Wire scanner	Transverse beam size	2

†Experimental equipment in crossing regions

processors. The other end of these striplines can be shorted to the beam pipe, since the beam direction is known. Position monitors of type 1, 2 and 3 have one end shorted; type 1 measures horizontal or vertical, type 2 (8 cm) and type 3 (13 cm) measures horizontal and vertical position. The 12 monitors at the DX dipoles will see both beams. Thus, in order to distinguish the two counter-rotating beams, these type 4 monitors will be directional coupler types, with both ends terminated into 50 Ω coax, and measure horizontal and vertical beam position. Care will be taken in the design of all monitors to minimize reflections between the stripline ends and the coaxial feedthrough. This will help avoid any resonances that could contribute to the narrowband impedance of the collider rings.

The 20 cm length of a typical monitor leads to a broadband transfer impedance with a maximum at about 350 MHz. A convolution of the monitor's response with the temporal

Table 8-2. Position Monitor Inventory

Style	Nominal Aperture	Number of Signal Cables Per Monitor	Location	Number of Monitors
Type 1 (cold)	8 cm	2	Q10 - Q10 (all Arc Quads)	276
			Q9	24
			Q6	24
			Q5	24
Type 2 (cold)	8 cm	4	Q8	24
			Q7	24
			Q4	24
Type 3 (warm)	13 cm	4	Q3	24
Type 3 (cold)	13 cm	4	Q1	24
Type 4 (warm)	13 cm	8	DX	12

characteristics of the bunch that is a few nanoseconds long leads to a signal with a broad spectral peak at about 100 MHz. Therefore, the front end electronics should have its passband centered near this frequency. In order to resolve individual bunches, this passband should be at least tens of MHz wide. The position monitor electronics will provide a combination of analog signal conditioning followed by digital signal processing. Typical functions provided will include: average closed orbit measurement, single bunch measurement, turn-by-turn buffering, and system calibration. In addition, the digital signal processor and the timing system interface should allow flexibility for future expansion in software.